THE DEVONIAN SECTION OF ITHACA, N. Y.[1]

HENRY SHALER WILLIAMS
Ithaca, N. Y.

At a meeting of the American Association for the Advancement of Science, June 29, 1906, the following chart was exhibited before Section E with explanations (an abstract of which is given below), under the title "Revision of the Geological Section Running through Ithaca, N. Y."

REVISED CLASSIFICATION AND NOMENCLATURE OF THE SECTION PASSING THROUGH ITHACA, N. Y.

Series	Formations	Members and Lentils	
Erie Division or Series of Vanuxem	Chemung (shale and sandstone) formation	Fall Creek conglomerate lentil	0–10′
		Wellsburg sandstone member	600–650′
		Cayuta shale member	600′
	Nunda (shale and flagstone) formation	Enfield shale member	550–800′
		Ithaca shale member	80–460′*
		Sherburne flagstone member	188–260′
	Genesee shale formation		125′
	Tully limestone formation		10–30′
	Hamilton shale formation		1035′
	Marcellus shale formation		125′
	Onondago limestone formation		125′
	Oriskany sandstone formation		0–4′

*In the chart as published in *Science* (Vol. XXIV, p. 366) this figure is 300′; see beyond remark on thickness of Ithaca.

ABSTRACT

The accompanying chart expresses the result in classification and nomenclature of the resurvey of the section of the Devonian passing through Cayuga Lake valley and Ithaca, between the Third and Fourth Districts of the original geological survey of the state

[1] Published by permission of the Director of the United States Geological Survey.

of New York made by Messrs. Vanuxem and Hall, and regarded by them as the standard section of the portion of the Devonian there represented. The revision was based upon a critical study of the composition, sequence, and range of the fossil faunas gathered in constructing the folio map of the Watkins and Catatonk quadrangles now in progress. The classification into taxonomic categories (i. e., series, formations, members, and lentils) is in accordance with the rules of classification and nomenclature of the United States Geological Survey as published in the *Twenty-fourth Annual Report* for 1902–3.

The *Nunda (shale and flagstone) formation* is the stratigraphic equivalent of the Portage or Nunda group of Hall, the standard section of which is in the Genesee valley; the term "Portage" having been dropped from the name because it was already specifically applied to the upper sandstone member of the Nunda formation of the Genesee valley. The lithologically discriminated members (Cashaqua, Gardeau, and Portage) there recognized are not distinguishable in the Ithaca section, which is divided into the *Sherburne flagstone*, the *Ithaca shale*, and the *Enfield shale members*. The term "Enfield" is applied to the latter member for the town of Enfield, where its typical exposures are found.

The boundary between the Nunda and Chemung formations is established on the generic change in fossils taking place at the horizon indicated. The more prominent of the new genera first appearing in the Chemung of this section are Dalmanella, Douvillina, and the species *Spirifer disjunctus*.

The *Cayuta shale member* contains the typical Chemung fauna of Chemung Narrows; and the name "Cayuta" is applied for Cayuta Creek along the sides of which, from Cayuta Lake to its discharge into the Susquehanna River, the typical exposures are met with. The upper boundary of the Cayuta member is marked by the fourth (above the Hamilton), and highest at present known, zone of *Tropidoleptus carinatus*, called the *Swartwood Tropidoleptus zone* for its conspicuous outcrop southwest of Swartwood at about 1,600 feet altitude above sea-level.

The second member of the Chemung formation is named the "Wellsburg sandstone member" for its outcrop from Wellsburg

upward into the high hills of Ashland, near the top of which the member is terminated by a thin conglomerate lentil called the *Fall Creek conglomerate lentil.* Immediately below this conglomerate the horizon is indicated by a band of thin-bedded sandstone, often calcareous, containing a great number of shells of *Leptostrophia nervosa* and *Orthothetes chemungensis*, to which the name *Ashland Leptostrophia zone* is applied.

It was noted that the formations of this section, extending from the top of the Onondaga limestone formation to the top of the section, belong to the Erie division of Vanuxem and Hall. This constitutes a natural *series* according to the rules of the Survey; the upper boundary of which, according to the original definition, should be the Catskill division (or series). Although the Wellsburg sandstone member appears to be the upper member of the Chemung formation of this particular section, the author expressed the conviction that the stratigraphic horizon of the Fall Creek conglomerate does not mark the termination, chronologically, of the Chemung fauna.

DISCUSSION

The original definition of the section.—This geological section of the Devonian rocks running through Ithaca was constructed along the boundary line between the Third and Fourth Districts of the state. Lardner Vanuxem wrote the *Final Report on the Third District* (1842), and James Hall the *Final Report on the Fourth District* (1843). The adopted classification and nomenclature of the Paleozoic rocks, up to the base of the Carboniferous, for North America has been constructed on the general lines which were announced chiefly by Vanuxem and Hall, and published in these two reports.

The significance of this particular section was expressed by Vanuxem in his report (1842), in the following passage:

> The Erie division embraces the rocks above those of the Helderberg division, extending to the Catskill group. It presents through several counties on both sides of the boundary of the Third and Fourth Districts two well-defined parts, separated by the Tully limestone and the Genesee slate; these latter are boundary masses of the two parts, being comparatively very thin, and of no great extent of range. The lower part of the division consists of the Marcellus shales and the

Hamilton group; and the upper portion contains the different sandstones and shales below the rocks at Ithaca, subsequently to be mentioned, and the Ithaca and Chemung groups. The distribution of the rocks of the upper part of the Erie division, under the heads of Sherburne flags, Ithaca group, and Chemung group, was founded upon observations made with Mr. Hall, commencing along Cayuga Lake, going south from Ludlowville by Ithaca, and from thence to the Pennsylvania line. The rocks, therefore, along that section, especially the upper ones, are the standard of reference, or types of those of their name. (P. 170.)

From this quotation it is evident that this section was adopted by Vanuxem and Hall as the standard section, and its subdivisions as the standard subdivisions, of that portion of the geological column which was then called the Erie division of the New York system. The nomenclature applied by Vanuxem to this standard section, expressed in tabular form and in natural order of sequence, is as follows:

Catskill division	28 Catskill group
Erie division	27 Chemung group
	26 Ithaca group
	25 Portage or Nunda group
	24 Genesee slate
	23 Tully limestone
	22 Hamilton group
	21 Marcellus shales
Helderberg division	20 Corniferous limestone, etc.

The rocks considered in the present paper are the upper four subdivisions of the Erie division of the New York system.

Original application of the term "member."—The term "member" was used in the text, both by Vanuxem and Hall, to designate a subdivision of a group which offered some local distinguishable characters, but was not regarded as of sufficient importance to incorporate in the nomenclature of the general classification proposed. Thus, in describing the Hamilton group, Vanuxem says: "This group takes its name from the town of Hamilton, in Madison County, which contains no other rocks, and where the best opportunity exists for examining some of the important members of which it is composed;"[1] and Hall, in describing the fossils of the Cashaqua shale, says: "In the Cashaqua shale, or lower member of this group, there are several species of shells which have not been seen in any

[1] *Geology of the Third District,* p. 150.

other rock, and at the same time there are no fossils found in them which are known in other rocks beyond the group."[1]

The taxonomic rank of the original subdivisions of the section.—In geological literature subsequent to the publication of these reports the geographic terms above mentioned have been applied in a technical sense to subdivisions of the geologic column of varying taxonomic value. Thus we find "Chemung group, period, series, beds, and formations;" and in the latest edition of Dana's *Manual of Geology* we find "Hamilton period" described as consisting of the Marcellus and Hamilton epochs (p. 576), and again the "Hamilton group as composed of the Marcellus shale, Goniatite limestone, Hamilton beds, and Tully limestone (p. 593).

Rules of classification and nomenclature.—Confusion of this kind has made it necessary to construct definite rules for nomenclature and classification in which the taxonomic rank of the subdivisions is indicated.

Two well-known examples of such rules are in use. The one was proposed by the Congrès géologique international; the substance of which was published as a report of the *Commission pour l'uniformité de la nomenclature*, made to the Berlin congress in 1885 by M. G. Dewalque, secretary of the commission. The other, as finally perfected, was published in the *Twenty-fourth Annual Report* of the Director of the United States Geological Survey in a passage headed "Nomenclature and Classification for the Geological Atlas of the United States" (pp. 21–27). The first may be said to be the set of rules for the construction of the geologic map of Europe; the second, rules for the construction of the geologic map of the United States.

No attempt will be made in this place to describe either of these sets of rules; suffice here to explain a fundamental difference between the two schemes. Dewalque's scheme was an attempt to unify the nomenclatures of the various nations of Europe by first establishing a set of names to distinguish the order of rank of the divisions to which they were to apply. Thus, to divisions of the first rank (i. e., the largest named divisions of the rock column) the term "group" (French *groupe*) was applied; second, *système* was the

[1] *Geology of the Fourth District*, p. 243.

name proposed for divisions of the second rank (i. e., subdivisions of groups); third, *séries* was the name for the third-rank divisions; fourth, *étage*, for the fourth rank; and, fifth, *assise* for the fifth rank. The terms, *ère*, *période*, *époque*, *âge* were proposed for the time divisions corresponding to the respective stratigraphic divisions of the first list. In this scheme "systems" were the systems in common use. Agreement as to which of the system names should be retained was settled by the congress. Finally it was proposed that all the names of each particular rank should receive the same ending: *-aire*, *-ique*, *-ian;* and thus names show by their endings the rank of the division to which they are applied.

The fundamental difference from all this, seen in the rules of the United States Geological Survey, is the adoption of a cartographic unit and calling it "formation."

The formation the unit in American classification.—In rule 2 it is stated: "In all classes of rocks the cartographic units shall be called 'formations.'"[1] A "sedimentary formation" is defined, viz.: "Each formation shall contain between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character." In other words, the unit division of stratigraphic rocks recognized for mapping, and hence for classification purposes, is a mass exhibiting unity of composition. Provision is made further in the rules for recognizing and mapping "especially developed parts of a varied formation" and calling them members, "*if they have considerable geographic extent*," and and lentils "*if their distribution is more limited.*"[2]

The units of the time scale, however, are, by the United States rules, said to be "periods"—the time equivalent of the standard geologic systems (rules 14 and 15, p. 25), and "for purposes of general correlation formations shall be referred to the standard systems," principally by paleontology. Thus, in classifying and correlating formations with each other, the physical units in the United States are "formations," which may be gathered into aggregates on the basis of correlation of their fossils with standard systems, all of which are in fact represented typically in Europe; but they

[1] *Twenty-third Annual Report*, p. 23.

[2] *Ibid.*, p. 24.

(the formations) are subdivided on the basis of differences in composition locally expressed.

Systems the European units of classification.—In Europe, practically, the "systems" are the primary units found already defined, named and in common use; and subdivisions of the systems are called respectively, according to their order of rank, *séries*, *étages*, and *assises* (these are the French terms).

Terms "group" and "series."—The terms "group" and "series" are also adopted in the United States Geological Survey rules, but they are there used for aggregates of formations, subordinate to systems and determined by local structure rather than simple correlation. Rule 20 sets forth this practice.

> Within the system smaller aggregates of formations may be recognized which shall be called "series," and these may be divided into subordinate groups of formations . . . . These minor aggregates should be formed so as to express the natural relations of the formations of the particular province rather than to conform with divisions recognized elsewhere.

The fundamental difference is exhibited in this rule 20: "Systems" are subdivided in Europe into *séries*, *étages*, *assises;* in America "formations" are aggregated into "groups," "series," and "systems."

In practice American geologists, unless actually working on the survey under the rules of the United States Geological Survey, are more accustomed to adopt the principles of the European rules than those of the United States Geological Survey. This result is perhaps because the European system lends itself better to the use of textbooks and colleges.

Uncertainty as to the definition of "formation."—In the present revision particular attention has been given to meeting the requirements of the rules of the United States Geological Survey. To do so, one of the first, and certainly an important, task required of the investigator is to determine which of the subdivisions of the section proposed by Vanuxem is a "formation" under the rules. Vanuxem realized the nature of the problem when he wrote:

> There are difficulties in the beginning of most, if not all, subjects. Those in the three groups under consideration arise from the little difference in their mineral characters, which, for distant points, cannot be relied upon. The change,

too, in the fossil characters is not so marked as to be at this time available. . . . What has caused geology to advance with rapid strides has been a knowledge of fossils, and when those of the upper part of the Erie division shall have been fully examined, and the kind determined which are limited to a group, and those which are not, then the difficulties will be at an end. (P. 172.)

Vanuxem in 1842 may have estimated too highly the results to be attained by a study of the fossils, but of the nature of the results he had a clear conception.

Neither of the sets of rules above referred to has given an intimation of the way by which we are to distinguish the size (in thickness of strata) of the geological unit, either of classification or for mapping purposes. How thick may a "system" or an *étage* of Dewalque's report be? or, How may a "formation" of the United States rules be distinguished from a "member" or a "group"? The raising of these questions will doubtless call forth scarcely two replies alike. In new work as in the old, the individual is left to draw the limits or boundaries of his "formation" as he will. The literature indicates that usage has been as diverse as is the modern practice.

The fact remains that it is all-important to discover if there may be some means of discriminating between the major and the minor divisions of the geological column.

The taxonomic rank of the subdivisions of the first New York survey.—The specific problem now before us is regarding the rank to be assigned the subdivisions originally recognized by Vanuxem in the Ithaca section.

The Portage or Nunda group.—Vanuxem described the first subdivision above the Genesee (no. 25) as the Portage or Nunda group. It is evident that it is only by correlation that this name is applicable to a part of the Ithaca section. The typical section of the Portage or Nunda group is found in the Genesee valley and is defined in Hall's *Report of the Fourth District.* In that region the "group" is composed of three subdivisions, viz., Cashaqua shales, Gardeau shale and flagstone, and Portage sandstones. It is fair to assume that the taxonomic rank of these subdivisions be tested in the original section, and that the application of the terms to the section at Ithaca rests upon correctly correlating its rocks with those of the original section in the Genesee valley.

Rule 3 of the United States Geological Survey *Rules of Nomenclature and Classification* contains the following provision for discriminating a "formation":

> Lines of separation are drawn at points in the stratigraphic column where lithologic characters change, or where there are breaks in the continuity of sedimentation or other evidence of important geologic events.

In the original definition the line at the base was drawn where the "soft argillaceous rock of a green color" of the Cashaqua shale succeeds the "fissile black shale" of the "Genesee black shale." The upper boundary, although marked by the "thick-bedded sandstones" (Portage sandstones) was distinctly drawn on paleontological evidence. Hall stated:

> Still it must be acknowledged that in lithological characters there is no abrupt change, or evidence of very different conditions in the ocean from which they were deposited, from the termination of the Tully limestone, to the final deposition of the Chemung group (p. 229).

After stating that there are some general differences noted on passing upward by which the Portage and Chemung rocks can be distinguished as masses, he adds:

> When we apply the test of organic remains, we find an equally or even more strongly marked difference in the two groups, and upon this alone a distinction between the two should be made.

Later studies have confirmed both of these points, and upon purely lithologic grounds it would be necessary to go down to the Tully limestone to find a sharply defined lithologic lower limit for the rocks in question. There is no satisfactory upper limit of a purely lithologic nature—not till we reach a definite pebbly conglomerate or a red sandstone such as has been supposed to mark the upper boundary of the Chemung formation. Nevertheless, the rule defines more clearly what is intended by "unity of constitution" by stating that in determining the unity of constitution, which is to characterize a formation, "all available lines of evidence, including paleontology, shall be considered" and "when two formations of closely similar lithologic character are in contact, it will sometimes be necessary to depend almost entirely on the contained fossils in separating them."

These statements distinctly apply to the case in hand. The

unity of the fossil fauna of the three subdivisions of the original Portage or Nunda group, the definite change in faunal composition passing on downward into the Genesee, and that observed on passing upward into the Chemung in the region of the original section, together give ample reasons for regarding this subdivision as a "formation" in the technical sense of the rules. Each of the parts, Cashaqua, Gardeau, and Portage, naturally falls into the nomenclature of "member" as defined in rule 5.

The name of the formation.—There is thus a formation composed of three members already described in the section of the Fourth District of New York to which a definite name was applied by Hall, but to the final adoption of the names of the subdivisions of the Ithaca section rule 7 applies. Rule 7 reads:

> In the application of names to members, formations, and larger aggregates of strata the law of priority shall generally be observed, but a name that has become well established in use shall not be displaced merely on account of priority.

It is well known that the name "Portage" has been largely used for the Portage or Nunda group; there is therefore some question as to the proper name to apply to the formation. Hence, the rule of common-sense must be called into use. Since the rules contemplate the application of distinctive terms to formations, as well as to members and larger aggregates of strata, it is clear that the same geographic part of the name cannot be applied distinctively to two separate subdivisions. The law of priority applies to Portage as the distinctive name for the upper sandstone member of the Portage or Nunda group; this excludes the use of the abbreviation of the group name to Portage by dropping from it the words "or Nunda." It is therefore proposed to rectify the usage by taking the second of the synonymous geographic terms, and omitting "Portage or," from the original name, to leave Nunda as the geographic part of the formation name. Thus the revised nomenclature for Hall's "Portage or Nunda group" is "Nunda formation," composed, in the Genesee section, of the Cashaqua shale, Gardeau flagstone, and Portage sandstone members.

The Nunda formation in the Ithaca section.—A critical examination of the *Final Reports* of the Third and Fourth Districts indicates

that Hall and Vanuxem were not in perfect agreement regarding the correlation of the Genesee and Ithaca sections. Hall evidently believed that the Ithaca group of the annual reports was not distinct from, but a lower portion of, the Chemung group. The equivalent of the Portage or Nunda group according to that view would be found below the Ithaca. Vanuxem, on the other hand, originally intended "to unite the Sherburne and the Ithaca masses, not having discovered in the district those leading characters by which they could be readily distinguished."[1] Both authors evidently expected the fossils, when fully studied, would solve the perplexity.

In the final reports on the paleontology, which was chiefly prepared by Hall, the Ithaca fossils were described as from the Chemung group, thus perpetuating the view held by Hall in 1843.

A review of the section and contained fossils was made by the writer, and published in 1883 as *Bulletin No. 3* of the United States Geological Survey.[2] In that paper it was shown that the fauna of the Sherburne portion of the section below the Ithaca group was present also above the latter; that there are 600 feet or more of strata separating the Ithaca from the base of the Chemung; and that the Ithaca and Chemung faunas are distinct.

The investigations recently undertaken, in preparing the areal map of the Watkins Glen quadrangle, have confirmed the correctness of these points and have demonstrated more clearly the true correlation of the two sections. It has been shown that, upon passing westward from the Ithaca section, the molluscan fauna characteristic of the Nunda formation prevails throughout the whole 1,300 feet of strata following the Genesee shale, with (at the head of Seneca Lake) only a sparse representation of the Ithaca fauna appearing in a few narrow beds in the lower portion of the section. West of Seneca Lake scarce a trace of the Ithaca fauna is discovered, but, when present, it is always below the first appearance of the Chemung fauna. The fauna in the Grimes sandstone of the Naples section reported by Clarke and Luther appears to contain a trace of the Ithaca fauna.[3]

[1] *Report of Third District*, p. 171.

[2] Henry S. Williams, "On the Fossil Faunas of the Upper Devonian along the Meridian of 76° 30′ from Tompkins County, N. Y., to Bradford County, Pa."

[3] New York State Museum, *Bulletin No. 63*, p. 63.

Peculiarities of the formation east of Ithaca.—On passing east of the Ithaca section, into the Dryden and Harford quadrangles, the beginning of the Chemung fauna is found at the same stratigraphic horizon; but the Nunda fauna becomes rare and limited in range in the Enfield member. The upper limit of the Ithaca fauna proper rises higher in the strata, and a successor of the Ithaca fauna appears in the upper portion of the Enfield, below the Nunda Chemung boundary. In the Chenango valley section there is little, if any, trace of the Nunda fauna above the Sherburne sandstone, which there represents, as shown by Prosser,[1] the portion of the Nunda lying below the Ithaca at Ithaca rather than the whole Nunda of the Genesee valley section. In this eastward extension of the portion of the section called "Nunda formation" in the Genesee valley the species of the Nunda fauna are very rarely discovered, but in place of them an increasing number of species of the Hamilton formation appear, mingled with others of the Ithaca fauna.

In these strata there are representatives of three faunas, viz., those typically expressed in the Hamilton, the Nunda, and the Chemung formations. In single sections they appear in the order named; but this order of succession can not be interpreted into an assumption that the time range of each is separate. The faunas undoubtedly lap over in time. In stratigraphy this fact is expressed by saying that the stratigraphic horizon at which one fauna is succeeded by the next in a particular section does not represent the same moment of time at which the like succession occurs in some other section. As has been explained elsewhere,[2] the principle involved is the geographic shifting of two contemporaneous faunas over the same ground. The fact of this gradual replacement of the Nunda fauna on passing eastward by representatives of the Hamilton fauna is indicated in the Ithaca section by the appearance in the midst of the normal faunas lying above the Hamilton formation of thin beds four times repeated, holding a nearly pure Hamilton fauna. Discussion of this subject will be taken up later.

[1] See *Fifteenth Annual Report* of the State (New York) Geologist, pp. 112, 113, 119, 134, and 221.

[2] Henry S. Williams, "Shifting of Faunas, etc.;" *Bulletin of the Geological Society of America*, Vol. XIV (1903), pp. 177–90.

The members of the Nunda formation at Ithaca.—From these facts the conclusion is drawn that the stratigraphic equivalent of the Nunda formation of the Genesee valley is represented in the Ithaca section by three subdivisions or members, viz., *Sherburne flagstone member*, which is the westward extension of Vanuxem's Sherburne flagstones of the Chenango Valley; *Ithaca shale member*, the equivalent of Vanuxem's Ithaca group; and *Enfield shale member*, a member not recognized by Vanuxem or Hall, but first reported by Williams in *Bulletin No. 3* of the United States Geological Survey (p. 30) in 1884 as "Upper Portage." The name "Enfield" is proposed for its outcrop in the town of Enfield, west of Ithaca. The rocks of the Enfield are shales, flags, and thin sandstones as in the Sherburne; the fauna is similar to that of the Sherburne flags below; and the thickness in the Ithaca section is from 600 to 800 feet.

Two reasons may be given for not recognizing the original subdivisions of the Nunda in the Ithaca section. (1) Though the lithologic characters upon which these three members (i. e., Cashaqua, Gardeau, and Portage) were founded become more pronounced going westward, on passing eastward before reaching Ithaca they fail to be distinctive of the lower, middle, and upper portions of the formation. (2) The fauna which was recognized by Hall in 1843 as characteristic of the Cashaqua member prevails throughout the Nunda formation of the Ithaca section. Hence the subdivisions of Hall's original Portage or Nunda group are discarded in the definition of the Ithaca section.

Discrimination of the members.—The Ithaca member is recognized on the basis of its fauna; the portion of the Nunda lying below the Ithaca member is correlated lithologically and stratigraphically with the Sherburne flagstone member of Vanuxem, and the upper portion, lying between the Ithaca member and the base of the Chemung formation, is for the first time given a distinctive name, i. e., the Enfield member. Lithologically and paleontologically the Sherburne flagstone and the Enfield shale or flagstone are very similar; stratigraphically they are separated by the shaly member bearing the characteristic Ithaca fauna. The range of this Ithaca fauna is restricted to a zone of about 80 feet in the Watkins expo-

sure; this range is increased on passing eastward, and at the Ithaca meridian is some 300 feet. The thickness of the Ithaca member, estimating it from the upper Reticularia lævis zone of the Sherburne to the upper Ithaca Reticularia lævis zone is approximately 460 feet at Ithaca.

Lithologic definition of the Nunda formation.—Thus is established a definite stratigraphic subdivision of the Devonian system of formational rank of which the technical name is "Nunda formation," composed of the members Cashaqua, Gardeau, and Portage in its typical outcrop in the Genesee valley, and of the Sherburne, Ithaca, and Enfield members in the Ithaca section.

Lithologically it is defined as an irregular combination of fine fissile shales, either light or dark in color, with, generally, thin-bedded and occasionally thicker beds of sandstone. The shales, in general, are more conspicuous in the lower half; the thicker sandstones are more frequent in the upper part. The light-greenish-colored shales seen in the western part of the state are inconspicuous in the eastern sections. The tough, thin-bedded, often wave-marked sandstone, called "flagstone" from its common use in paving sidewalks, is more frequent in the eastern than in the western outcrops.

THE BLACK SHALE BANDS

The fissile black shales, similar lithologically to the Genesee black shales below, appear throughout the vertical thickness of the formation at various horizons, sometimes of 20 to 50 feet thickness, presenting locally great uniformity. These fissile black shale masses rapidly change their appearance laterally by the intrusion of sandstone bands interrupting the shales, and altering the aspect of exposures to that of the ordinary type of shale and thin-bedded sandstone so characteristic of the whole mass. A typical example of this type of shale is seen at the base of the Ithaca group, near the foot of the hillsides at Ithaca. Locally it seems conspicuous, and I defined and indicated it as the "Ithaca Lingula shales" in the *Bulletin No. 3* of the United States Geological Survey in 1884.

Clarke has defined other local expressions of it under the names *Middlesex black band*, *Rhinestreet black band*, and *Dunkirk black*

band. When the resurvey of the Watkins Glen quadrangle was begun, I expected that these black bands would prove of value in tracing and classifying the rock horizons from one quadrangle to another. It was discovered, however, in the course of the survey, that any particular mass of this fissile black shale does not retain its peculiarities with sufficient uniformity to serve as a reliable mark of a definite horizon.

The same may be said of local thick-bedded sandstones; they are also, so far as thickness is concerned, confined to narrow local distribution. The mode of change in the structure is through a breaking-up of the thick sandstone bed, by increase of shaly bands in its midst, reducing it to a mass of thin-bedded sandstone and shales. When for a considerable thickness no sandstone bands are present, the section appears as a mass of fissile shales; when the shale layers diminish, the sandstone bands run together, and become beds of sandstone separated irregularly by shale bands in which case the sandstones become the conspicuous features in the outcrops.

It was also discovered that the faunas are associated with particular classes of sediments; hence, where similar types of strata appear the fossils are also alike—irrespective of stratigraphic position within the formation through which the same fauna ranges. These are some of the reasons for discarding from the systematic nomenclature all such subdivisions of the strata as are of local narrow distribution.

Subdivisions of the Nunda formation not recognized in the Watkins Glen and Ithaca quadrangles.—Other names have been applied to subdivisions of the formation elsewhere where they are considered to be of member or lentil value. They have been discarded whenever the definitions given them, lithologic or paleontologic, fail to apply to any recognizable portions of the section in the Ithaca region.

According to the United States Geological Survey rules, it has been considered illegitimate to continue to apply member and lentil names to corresponding stratigraphic portions of a formation, when the section ceases to exhibit the lithologic or paleontologic characters upon which discrimination of the members was based. The formation name should be applied, according to rule 4, "as

far as the formation can be traced and identified by means of its lithologic character, its stratigraphic association, and its contained fossils." But the member or lentil is a "specially developed part" of a formation; it is therefore considered inappropriate to apply the member or lentil name in absence of the characters distinguishing it.

For these reasons the terms "West River shale," "Cashaqua shale," "Parrish limestone," "Rhinestreet black shale," "Hatch shale and flags," used by Clarke and Luther,[1] are not deemed appropriate names to apply to portions of the Nunda formation of the Watkins or Ithaca quadrangles, however appropriate they may be for the sections of Canandaigua Lake or in the Genesee Valley.

Paleontological definition of the Nunda.—Paleontologically the Nunda formation is well characterized by the fauna ascribed to it by Hall in the Fourth District report of 1843 (pp. 241–47). The species named by him are (giving the original names): *Fucoides graphica*, *Fucoides verticalis*, *Avicula speciosa*, *Ungulina suborbicularis*, *Bellerophon expansus*, *Orthoceras aciculum*, *Clymenia complanta*, *Goniatites sinuosus*, *Pinnopsis acutirostra*, *Pinnopsis ornatus*, *Delthyris lævis*, *Cardium? vetustum*, *Orthis tenuistriata*, *Lucina retusa*, *Nucula lineolata*, *Astarte subtextilis*, *Bellerophon striatus* (Bronn, Phillips), *Goniatites bicostatus*, and *Cyathocrinus ornatissimus*. These nineteen species have been more definitely defined and named, and a great number of other species have been added to them since 1843, but they clearly indicate the fauna. There are in Hall's list eight Pelecypoda, two Gastropoda, four Cephalopoda, two Brachiopoda, one Echinodermata, and two of uncertain classification. About 75 per cent. are Mollusca. Later study of the fauna shows the same dominance of this class. The Brachopods are conspicuous by their absence; and it is the dominance of Brachipods in the Ithaca fauna which distinguishes the zone in which they occur as a well-marked member of the formation. Lithologically the Ithaca rocks are not clearly distinguishable from the other rocks of the Nunda formation of this section, though they are paleontologically. This Nunda fauna was definitely recognized

[1] "Geology of the Watkins and Elmira Quadrangle," by John M. Clarke and A. Dana Luther, New York State Museum., *Bulletin No. 81*, 1905.

by me in 1884,[1] and it was then shown to range "through approximately 1300" feet, including the "Ithaca group." It was then spoken of as the *Cardiola speciosa fauna.* In 1886[2] this general fauna was differentiated into the several stages, *Lingula fauna*, characteristic of the black shales; *Cephalopod fauna*, found more frequently in the green shales; and the special *Cardiola speciosa fauna* also occurring in the greenish shales, but often disassociated from the Cephalopods. In 1887[3] these faunal distinctions were more fully elaborated and defined for the Genesee section. In 1885[4] J. M. Clarke described the fauna and flora of the Naples beds of Ontario county, there proposing the term "Naples beds" to include the Cashaqua and Gardeau members of the Portage or Nunda group of Hall; and in 1898 and 1904[5] the fauna was more fully elaborated by him under the name of the "Naples fauna," and its intimate relations to the European Intumescens fauna was also indicated.

ALTERNATION OF DISTINCT FAUNA

In the paper of 1887[6] the Nunda fauna was shown to run up in the strata at Hornellsville high enough to be mingled with species of the distinctive Chemung fauna.[7] This fact of the alternation of the representatives of two distinct faunas in the zone of transition from one fauna to another has been repeatedly observed in later studies. It led me to the necessity of assuming that two faunas normally appearing one above the other in direct succession owe their order of succession to shifting of their local habitat in the same oceanic basin (i. e., marine faunas), rather than to any absolute

[1] *Bulletin No. 3*, U. S. Geological Survey (1884).

[2] "On the Classification of the Upper Devonian," *Proceedings of the American Association for the Advancement of Science*, Vol. XXXIV (1886).

[3] Henry S. Williams, "On the Fossil Faunas of the Upper Devonian–the Genesee Section, New York," *Bulletin No. 41*, U. S. Geological Survey (1887).

[4] John M. Clarke, "On the Higher Devonian Faunas of Ontario County, New York," *Bulletin No. 16*, U. S. Geological Survey (1885).

[5] *Memoir No. 6*, New York State Museum, "Naples Fauna in Western New York," Parts 1 and 2 (1898 and 1904).

[6] *Bulletin No. 41*, U. S. Geological Survey.

[7] *Ibid.*, p. 80.

extinction of one and replacement by the other.[1] On such assumption the correlation of formations by fossils becomes a complex problem, for we cannot say that the last stage of the fauna of one locality occurs at the same stratigraphic horizon as at another locality. The range of this Nunda fauna (i. e., "Cardiola," "Portage," "Naples," "Manticoceras" fauna) has been shown to pass above the Ithaca fauna in the Ithaca section; at Hornellsville it is seen in contact, so to speak, with the Chemung, and traces of it also occur well up in the zone dominated by Chemung fossils. The result is that to be accurate in drawing formation lines on a paleontologic basis there must be recognized a zone of transition of greater or less extent in which either or both faunas may appear. The drawing of formational boundaries on lithologic basis is not more accurate; but the error is more difficult to detect. The actual number of feet thickness assigned to a particular formation in a local section often depends more upon the positiveness of the assumption as to the actual boundary stratum than upon the definiteness of the evidence of the correlation.

The passage from the Nunda fauna to the Ithaca fauna, from Ithaca back to Nunda, and from Nunda to Chemung can generally be detected within passage of a few feet of strata, the chief reason being that the faunas thus brought into direct sequence are different in their generic and, often, class composition. In the Nunda frail-shelled Pelecypods, Gasterpods, Cephalopods, and Arthropods of its lower orders dominate. In the faunas of both the Ithaca and Chemung formations, Brachiopods, Bryozoa, and Lamellibranchs of the Pectinoid type are the conspicuous forms. The assumption is made that this difference between the Nunda fauna and either the Ithaca or Chemung is intimately associated with environmental conditions of their habitats, hence the contrasted faunas are described as heterotopic in relation to each other.

Difficulty in separating the Ithaca from the Chemung fauna.—When the successive faunas are homeotopic, the difficulty of dis-

[1] Henry S. Williams, "Shifting of Faunas as a Problem of Stratigraphic Geology," *Bulletin of the Geological Society of America*, Vol. XIV, pp. 177–90; "The Correlation of Geological Faunas: A Contribution to Devonian Paleontology," and *Bulletin No. 210*, U. S. Geological Survey, (1903).

tinguishing their characteristics is greater. Clarke has recognized this difficulty in saying that

> it is extraordinarily difficult to fix on a division plane between the Ithaca and the overlying Chemung faunas, as the one passes into the other by easy gradation, and we are still somewhat at a loss in determining specific values indicial of the early stages of Chemung time.[1]

This difficulty has been met in the present revision by recognizing the reasons for the difficulty and drawing the lines accordingly. The reason why it is difficult to draw a stratigraphic horizon plane, separating two faunas in which a large part of the genera are identical and many of the species the same, is because of the evident similarity in composition of the two faunas. This similarity, I have assumed, is due to adjustment of the species of the faunas to like conditions of environment, but in different areas of distribution. The fact that the two faunas contain some distinctive species, associated with a second fact that in the New York province at least the one (Chemung) is always found higher in any single section than the other (Ithaca) fauna, together prove that distinguishing characters are of long standing, From this fact it is inferred that the two faunas developed their peculiarities in different areal centers. The differences are like those distinguishing the Arctic from the Florida faunas of the western Atlantic, or the faunas of the east coast of the United States of America from those of the coast of Europe. If these interpretations are correct, two kinds of differences should be capable of discovery, viz.: (1) differences in the evolution of the species of a common race, and (2) differences in the original stock of the two faunas, i. e., survivals of old races which have become extinct in one and have continued to live in the other.

If we attempt to draw the line of boundary between the two faunas, stratigraphically, it is necessary to assume that the later fauna is not the strict genetic successor of the earlier one, in spite of the close similarity in its species. Either barriers have been removed opening to a common basin the waters of separate basins, or general shifting of temperature by currents or by depth has produced such changes of general temperature that the two faunas have been forced

[1] "Naples Fauna of Western New York," New York State Museum, *Memoir No. 6*, Part 2, p. 213 (1903).

to shift their *locus habitans*. One fauna (the Ithaca) has either become partially destroyed or forced to migrate, while the other (Chemung) has entered for the first time into the region where the New York state rocks were being deposited.

In some particular section the change of occupation may take place suddenly so that the last of the Ithaca species will be brought into close contact with the first appearance of the Chemung, but this state of facts cannot be expected without some violent revolution, of which no evidence is here given. In some cases, particularly east of Ithaca, it is difficult to distinguish the passage, but for the reason that there the Ithaca fauna is in a later state of its evolution than at Ithaca, and thus the transition of species between the two homeotopic faunas is less conspicuous. This is due to the fact that such species as are present in both faunas are then in nearly the same stage of evolution; and, second, because the diagnostic species of both faunas are less in evidence where the Chemung fauna immediately follows the later stages of the Ithaca fauna than, farther west, where a long interval of time separated the period of the occupation by the Ithaca from the period of the income of the Chemung fauna.

[*To be continued*]